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Possible evidence of bone tool shaping by Swartkrans early hominids

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Abstract

Ever since Dart (J. Phys. Anthrop. 7 (1949) 1) interpreted certain bones from Makapansgat as tools, scientific consensus has fluctuated as to whether some bone objects from early hominid sites should be interpreted as artefacts, or the result of non-human taphonomic processes, which are known to produce pseudo-bone tools morphologically similar to human modified or used artefacts. Here we present possible evidence of bone tool shaping from Swartkrans (Members 1–3; ca. 1.8–1.0 Mya). Four horncores and the proximal end of an ulna used as tools in digging activities also have facets covered by parallel spindle-shaped striations characteristic of grinding. Identification of these traces as possibly resulting from deliberate shaping or re-sharpening of the bone tools is based on the characterisation of the use-wear pattern and other taphonomic modifications observed on the Swartkrans bone tools. This interpretation is also supported by the study of the remainder of the horncores from Swartkrans, horncores from other southern African Plio-Pleistocene sites (Sterkfontein, Makapansgat, Gondolin), modern horncores affected by pre- and post-mortem modification, ethnographic, LSA, African Iron Age and experimental bone tools shaped by grinding. These data suggest that early hominids had the cognitive ability to modify the functional area of bone implements to achieve optimal efficiency.

Keywords: Swartkrans; southern Africa; Early hominid; Bone tools; Taphonomy; Plio-Pleistocene

1. Background

Exactly where, when, for what purpose and by whom the first bone tools where used, and what the evolutionary, adaptive, and cognitive implications of such a use are, represent questions that have provoked considerable debate among researchers interested in early human culture [26,27,33,35,37,65,71,73,79,81,82,84,107]. The recent discovery of three complete wooden spears at the 400,000 year old site of Schoeningen [105] in Germany, confirms what was already known from Clacton [85] and Lehringen [106], namely that Middle Pleistocene hominids were quite capable of shaping wood with very specific techniques such as shaving and scraping. There is no reason to believe that this ability might not have been applied to other organic materials. Still, the identification of bone tools from Lower and Middle Palaeolithic sites remains a controversial issue. We know that bone was used as a raw material for implements in those periods due to the discovery of equid, bovid, reindeer phalanges, deer antler, long bones epiphyses and shaft fragments used for retouching stone artefacts from Middle and Upper Pleistocene sites in Europe [5,32,60,77,88,90,108].

Another example of intentionally shaped bone is the occurrence of Acheulean-type bifaces flaked on elephant long bone shaft fragments found at several Middle Pleistocene sites on the Italian peninsula and possibly at other contemporaneous European sites [14,15,92,110,119].

An increasing number of clearly shaped bones are reported from MSA sites from southern and central Africa [11,61,62,79,99]. These include barbed and unbarbed points, as well as a dagger-like object dated

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to between 90 and 60 Kya from Zaïre [29,121]; Yellen, pers. com.) though the chronological and stratigraphic context of these bone tools has been questioned [74].

In Europe, late Neandertal sites such as Arcy-sur-Cure and Quincay in France, Castelcivita in Italy, and Buran Kaya II in Crimea, dated to between 40 and 35 Kya, have yielded clear evidence of a complex bone technology, including personal ornaments, shaped and decorated awls and bone tubes ([43,45,56,122,123], with comments). These objects were most probably made by the late Neandertals, and not collected by them in Aurignacian sites or traded with invading anatomically modern humans as previously suggested. This is demonstrated by the presence of by-products of bone tool manufacture associated with Neandertal remains at the site of Arcy. It is still a matter of debate however, whether the production of these objects is the result of an autonomous cultural evolution of late Neandertals, or of their contact with anatomically modern humans colonising Europe.

Many other putatively shaped or used bone, antler, and ivory tools are reported from a large number of Lower [1,4,10,14,17,25,27,28,31,35,46,47,63,66,78] and Middle Palaeolithic sites [38,49–52,69,101,113–115] in Africa and Europe. The nature of this evidence has however been constantly called into question by studies demonstrating that a number of natural processes occurring during the life of an animal, or after its death, can produce pseudo-tools that have been, or may be misidentified as intentionally modified or used bones. The former include surface features resulting from the remodelling of the bone structure [40], vascular grooves [42,97], teeth use-wear [53], breakage and wear of deer antler [86] and elephant tusk tips [59,112]. The latter are more numerous and include gnawing or digestion by carnivores, rodents and herbivores [16,89,103,104,111], fracture for marrow consumption by hominids and carnivores [30,54,55], trampling [41,58] root etching [16], weathering [19] and the action of different sedimentary environments [20,76]. These and other works (see [18,96,98]) have made clear that the identification of contemporary analogues and their use in replication studies are crucial when assessing claims of early bone tool industries. It is by applying this approach for example, that Dart's theory for an early hominid "Osteodontokeratic culture" has been challenged [20,70,95]. Clearly, final assessments of purported bone tools require an integrated research strategy including a combination of analogues of different nature. Unfortunately, little research on possible early bone tools has been based on an interdisciplinary approach combining actualistic data, taphonomic analysis of the bone assemblages, replicative experiments and microscopic inspection of possible traces of manufacture and use.

2. Introduction

Here we focus on the oldest known evidence of the systematic use of bone tools [8,21,23,24,67,93] comprising long bone shaft fragments and horncores from Swartkrans (Members 1–3; ca. 1.8–1.0 Mya), Sterkfontein (Member 5; ca. 2.0–1.7 Mya) and Drimolen (2.0–1.5 Mya). According to Brain and Shipman's [24] microscopic analysis, 68 bones from Swartkrans were used for digging up tubers and working skins. However, this interpretation was not validated by comparing the purported tool morphology and wear pattern with those produced by natural processes. Alternative functional interpretations were not explored and contextual data (species, type of bone used, fracturing patterns, degree of weathering, bone flake morphometry, spatial distribution) not used to support the bone tool recognition. In two recent papers [8,44] we have reappraised this material using a multidisciplinary approach. Our analysis of the wear patterns on the Swartkrans and Sterkfontein pieces, on pseudo bone tools caused by known taphonomic processes, and on experimentally used bone tools confirm the anthropic origin of the modifications.

Taphonomic analysis of the Swartkrans assemblage reveals that the wear is a feature peculiar to the bones interpreted as tools and does not represent an extreme in variation of a taphonomic process affecting to a lesser degree the rest of the assemblage. This is supported by metric analysis indicating that the bone tools are a discrete population within the assemblage, in that longer, wider and more robust bone fragments were selected by hominids.

However, quantification of striation width and orientation comprising the wear pattern suggests that these tools were not used to extract tubers from the ground in the Sterkfontein area. The wear pattern instead more closely fits that created experimentally when bone is used to excavate termite mounds. Preliminary analysis of the undescribed 23 bone tools from the newly discovered hominid site of Drimolen [67] suggests that they might have been used in a similar way.

In a search for patterns of variation between bone tools from Members 1–3 at Swartkrans [9], no significant differences were found in the type and size of the bone fragments used, suggesting that no major changes occurred through time in the subsistence strategy in which the tools were involved. This implies that early hominids maintained a behavioural pattern involving a bone tool material culture that persisted for nearly a million years.

In the course of our analysis of the Swartkrans material we have also recorded other natural and anthropic surface modifications which are the focus of this paper. These traces, occurring on the tips of 4 robust horncores and one bone, are reminiscent of intentional shaping by grinding (Fig. 1). In order to make an

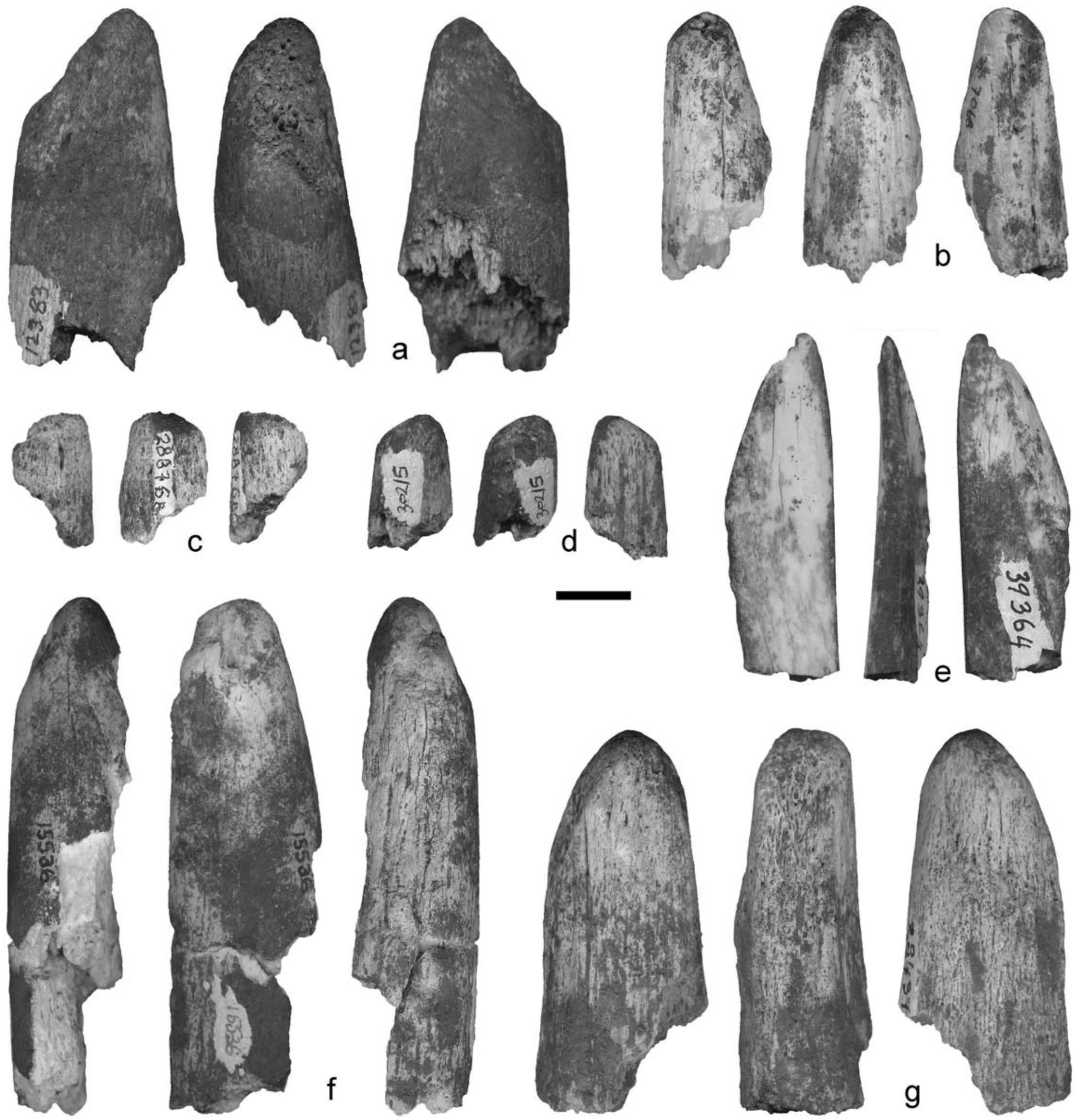

Fig. 1. Swartkrans bone tools bearing possible traces of grinding. (a) SKX 12383; (b) SKX 7068; (c) SKX 28876B; (d) SKX 30215; (e) SKX 39364; (f) SKX 15536; (g) SKX 28437. Scale = 1 cm.

informed assessment, we examined horncores from contemporaneous Plio-Pleistocene faunal assemblages, archaeological and experimentally ground bone tools, as well as modern reference collections consisting of pre- and post-mortem naturally damaged horncores. Results suggest that the Swartkrans horncores were intentionally shaped by grinding. This find indicates that shaping techniques conceived for bone material were used considerably earlier than previously thought. It also has implications for the view [79] that bone shaping represents one of the hallmarks of the emergence of behavioural modernity and advanced cognitive abilities.

3. Materials and method

3.1. Swartkans collection

The identification of possible traces of grinding on used bone tools was made in the framework of an ongoing research project concerning the use of bone tools by early hominids. As part of this project we have re-analysed part of the faunal collection from Swartkrans Members 1–3, comprising ca. 23,000 bone pieces [7]. This has allowed us to identify 16 previously unpublished bone tools [9]. Anthropic and natural modifications acting on the faunal assemblage and on

Table 1
Examined bone and horn cores

Collections studied	Institution	Bone material	Age/Culture	*n.*	References
Swartkrans Member 1	T.M.	horncore	ESA	49	[120]
Swartkrans Member 2	T.M.	horncore	ESA	73	[120]
Swartkrans Member 3	T.M.	horncore	ESA	76	[120]
Sterkfontein Member 5	T.M.	horncore	ESA	15	[75]
Gondolin Main Site	T.M.	horncore	ESA	18	[83]
Makapansgat Member 3	B.P.I.	horncore	ESA	33	[117]
Nelson Bay Cave (Robberg)	S.A.M.	bone	LSA	13	[36]
Nelson Bay Cave (Albany)	S.A.M.	bone	LSA	13	[36]
Die Kelders	S.A.M.	bone	LSA	11	[6]; [72]
Kasteelberg B.	S.A.M.	bone	LSA	2	[100]
Hunterian collection	U.W.M.S.	bone	LSA	5	
Rose Cottage	U.W.A.D..	bone	LSA	25	[118]
Goergap	UNISA	bone	LSA	12	[109]
Olieboomspoort	UNISA	bone	LSA	7	Boeyens unpublished data
Mapungubwe	U.P.	bone	Iron Age	5	[116]
Kleinfontein	T.M.	bone	Iron Age	7	[91]
San	U.W.M.S.	bone	Ethnographic	3	
Aboriginal Australian	U.W.M.S.	bone	Ethnographic	1	
Bovids	B.P.I.	horncore	Modern	24	
Bovids	I.P.G.Q	horncore	Modern	5	
Bovids	P.U.R.E.	bone + horncore	Experimental	20	
Total				417	

T.M.: Transvaal Museum; B.P.I.: Bernard Price Institute; S.A.M.: South African Museum; U.W.M.S.: University of Witwatersrand Medical School; U.W.A.D.: University of Witwatersrand Archaeology Department; UNISA: University of South Africa; U.P.: University of Pretoria; I.P.G.Q.: Institut de Préhistoire et de Géologie du Quaternaire; P.U.R.E.: Palaeo-Anthropology Unit for Research and Exploration.

the tools were recorded on representative samples from each member. Damage produced on bone tools by non-human taphonomic agents (carnivores, beetles, porcupines, sedimentary abrasion, root etching etc.) was recorded and its chronological relationship with use-wear established. After recognising possible traces of grinding on four horncore tips and a bone fragment, we re-examined the other 194 bovid horncores found in Members 1–3 (Table 1) to verify whether they exhibited similar modifications.

3.2. Comparative archaeological and palaeontological material

We analysed (Table 1) horncores from the South African Plio-Pleistocene sites of Makapansgat, Sterkfontein and Gondolin. Archaeological material included arrow points, awls and fish gorges shaped by grinding from the Later Stone Age sites of Nelson Bay Cave, Die Kelders, Goergap, Olieboomspoort and Rose Cottage. Bone tools from the Iron Age Mapungubwe Complex and the Kleinfontein site were also studied. San bone arrow points and link-shafts as well as one bone point made by aboriginal Australian, all shaped through grinding, constituted our ethnographic comparative material. We also examined the horncores and sheaths of several modern African bovids housed in modern reference collections.

3.3. Experimental material

Long bone shaft fragments from different medium-sized mammals and horncores from adult *Bos* and antelope were ground on granite and sandstone as well as the outer crust of termite mounds of the genus *Trinevitermes* present in the Sterkfontein Valley, Gauteng Province, South Africa (Table 1). In order to replicate the pattern seen on the possible shaped tools from Swartkrans the grinding was made without changing the orientation of the blank and the direction of the to-and-fro motion. Eight bone fragments were used to dig up *Hypoxis* bulbs near the Swartkrans site. Six similar pieces were used to dig in termite mounds [8].

3.4. Analytical procedures

We recorded the occurrence and type of breakage, degree of abrasion, presence of facets and striations on horncore tips from Swartkrans, Sterkfontein, Makapansgat and Gondolin. All Swartkrans horncores and bone tools, as well as the comparative collections were examined with a reflected light microscope, and relevant images digitally captured using a Nikon Coolpix 990 camera. High resolution dental impression material (Coltene President silicone paste) was used to make replicas of the tips of the Swartkrans tools with possible traces of grinding, a selected sample of the

Later Stone Age, Iron Age and ethnographic bone tools, as well as the experimentally ground bone. Positive casts made in RBS resin (T2L Chimie, France) were observed with a Scanning Electron Microscope [39]. Transparent resin replicas obtained using the same technique were also observed in transmitted light using a stereo-microscope, and the images digitally captured.

4. Results

4.1. The Swartkrans evidence

Possible traces of shaping by grinding appear different from the other human and non-human modifications recorded on the Swartkrans bone tools. Worn areas on these tools show an association of surface features not observed on bones modified by non-human agents [7,44]. These features include the presence of a rounded or pointed tip at one end of the specimen, associated with smoothing and polishing confined to an area of between 5 and 50 mm from the tip (Fig. 2). At a microscopic scale individual narrow striations cover the tip, but are absent from the remaining surface of the bone. These striations are oriented parallel or sub-parallel to the main axis of the bone and decrease in number and intensity away from the tip. They generally vary in width from 5 to 40 μm and can reach in a few cases 150 μm. This wear pattern results from repeated abrasion caused by fine-grained sediment with a limited range in particle size. This is suggested by the fact that striations follow the contours of the bone surface and affect concave areas such as medullar cavities and recessed surfaces of trabecular bone (Fig. 2(4), (6)). The worn areas are generally well preserved, although they are sometimes partially covered with manganese staining. Very few striations oriented perpendicular to the main axis of the bone – generally posterior to the longitudinal parallel striations and ranging between 100 and 400 μm in width – are recorded on some specimens. Carnivore damage in the form of scoring is recorded on two shaft fragments used as tools (SKX 16976; SKX 5010b). In both cases the fine striations resulting from use overlie the carnivore damage (Fig. 3). This demonstrates that early hominids made use of bones previously modified by carnivores.

Possible evidence of grinding (Fig. 1) was identified on 4 bone tools, including the distal portion of a right ulna (SKX 39364; collapsed ESA) and the apex of 3 bovid horncores (SKX15536, Member 2; SKX 28437 Member 3; SKX 7068, Member 1). On 3 additional horncores used as tools the traces of grinding are less clear (SKX 12383, Member 2; SKX 30215 Member 3; SKX 28876B, Member 3).

The ulna (Fig. 4) is one of 16 newly identified bone tools found during our examination of the Swartkrans faunal material [9]. Its tip is covered on both faces by the characteristic fine individual striations seen on the remainder of the bone tool collection. However, the medial aspect near the tip shows an elongated area covered by significantly wider parallel striations oriented obliquely to the bone main axis. Specimen SKX 15536 is a large bovid horncore of unknown taxon (Fig. 5). Near the tip, a distinct 15 mm long oval facet, located on the broader aspect of the specimen has removed the outer compact bone, revealing in places its inner trabecular structure. This facet is covered by obliquely oriented parallel striations indicating that the facet was created by contact with a solid abrading agent. These striations are absent from the remainder of the tip, which is smoothed and records instead individual sub-vertical striations. Piece SKX 28437 is an even more robust bovid horncore tip, with two opposing facets (Fig. 6). The abrasion has exposed the spongy bone on both facets confining the possible traces of grinding to their periphery. A similar pattern is recorded on the tip of horncore SKX 7068 (Fig. 7) on which clear multiple parallel striations cover a slightly convex facet. The areas on which these modifications occur have the same colour and patina as the remainder of the specimens, indicating that these modifications cannot be attributed to excavation or curation damage.

4.2. Comparative material

Bovid horncores generally have a naturally pointed tip that is protected during the animal's life by the horn sheath. Damage or intense wear of this keratin covering may result in exposure and trauma to the blood-rich underlying bone, with consequent remodelling of the bony tissue (Fig. 8 a). Remodelling of the horncore tip may also be caused by re-absorption of the bone tissue produced by disease, nutritional stress or the aging of the animal (Fig. 8b). Due to their loose bony structure, horncores that have lost the protection of their horn sheath after the death of the animal are particularly vulnerable to damage by a number of taphonomic agents. The majority of cow and buffalo horncores we examined in comparative collections show post-mortem damage consisting of elongated flaking (Fig. 8c) and/or erosion, indicating that preparation and handling of the specimens is sufficient to damage the tips. Once deprived of the horn sheath, skulls affected by weathering commonly show degradation of the horncore bone structure and a loss of the tips (Fig. 8d–e). However, some Alcelaphinae, Antilopinae and Aepycerotinae, such as wildebeest, hartebeest, springbok and impala have horncores with a denser bony structure that probably postpones the effects of taphonomic agents.

Only a minority of the horncores from Swartkrans and the other Plio-Pleistocene collections examined have complete tips (Table 2). The remainder bear two types of

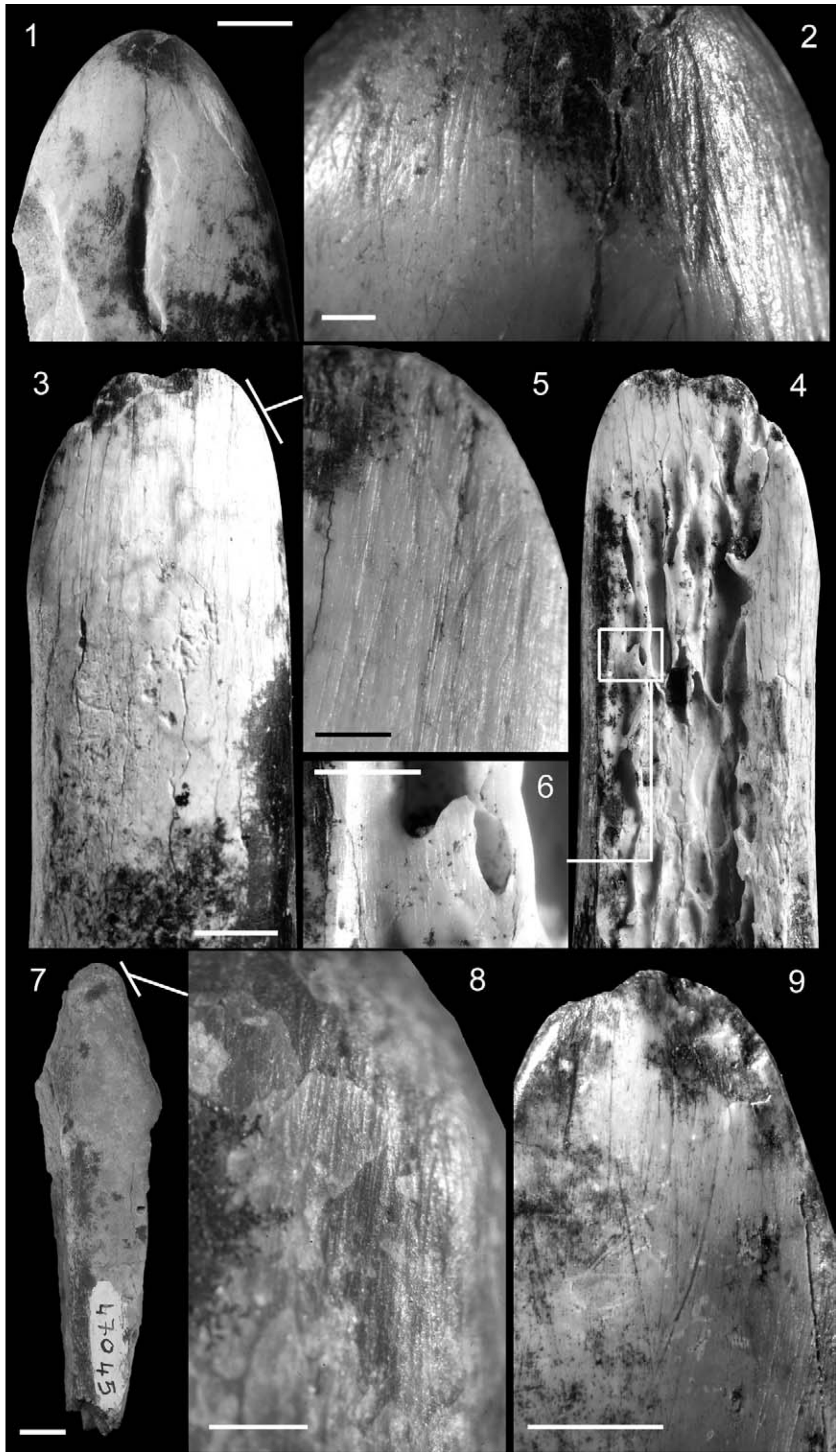

Fig. 2. Typical wear pattern recorded on the tips of the Swartkrans bone tools consisting of sub-parallel individual striations. (1–2) SKX 1142; (3–4) two aspects of SKX 35196; (5–6) close-up views of the same tool. Notice how striations affect concave areas of the spongy bone (6) indicating that fine loose abrasive particles were responsible for the wear pattern; (7–8) SKX 47045; (9) SKX 38830. Scale = 5 mm in 1, 3, 7, 9 and 1 mm in 2, 5, 6, 8.

alteration: clean, mostly transverse fractures, and irregular breakages of variable shape (Fig. 9). The former clearly result from the retrieval of heavily fossilised specimens from breccia blocks, as suggested by the clear difference in patina between the area exposed by the fracture and the outer surface of the bone (Fig. 9, top). The latter consist of composite adjacent stepped fractures narrowing the distal portion of the bone, or single obliquely oriented fractures resulting in a convex outline of the apex (Fig. 9, centre). These last fractures display

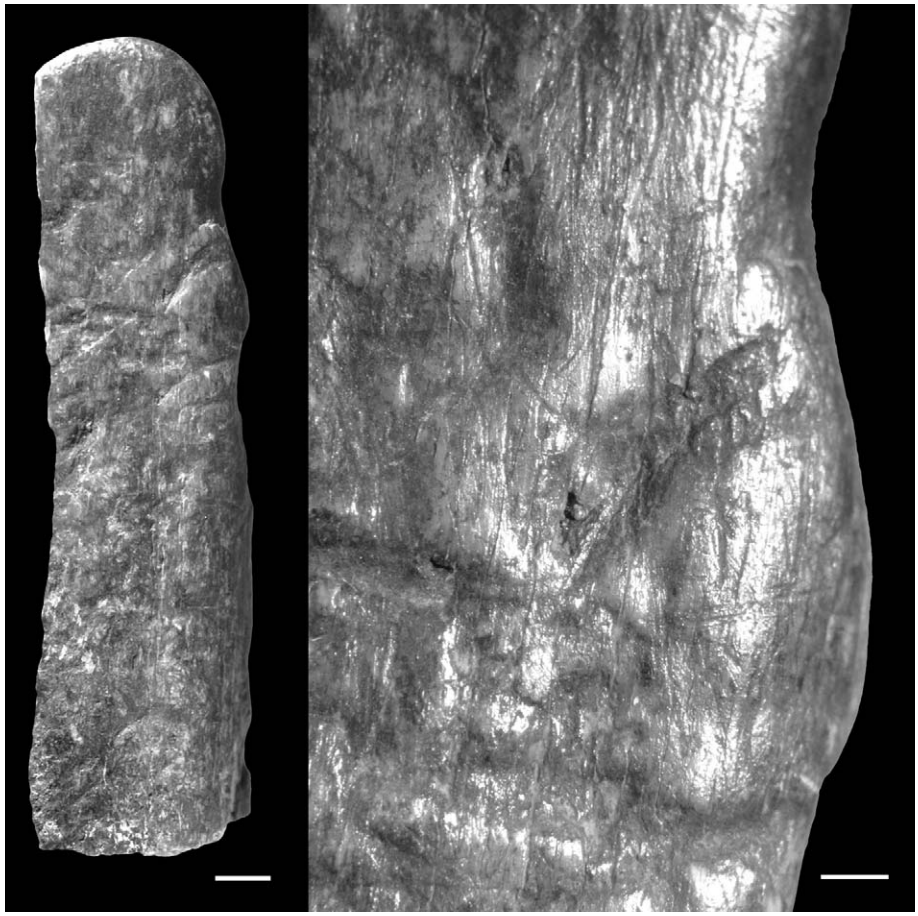

Fig. 3. Swartkrans bone tool SKX 16976 with striations produced by use overlying traces of carnivore tooth scoring. Left scale = 5 mm; right scale = 2.5 mm.

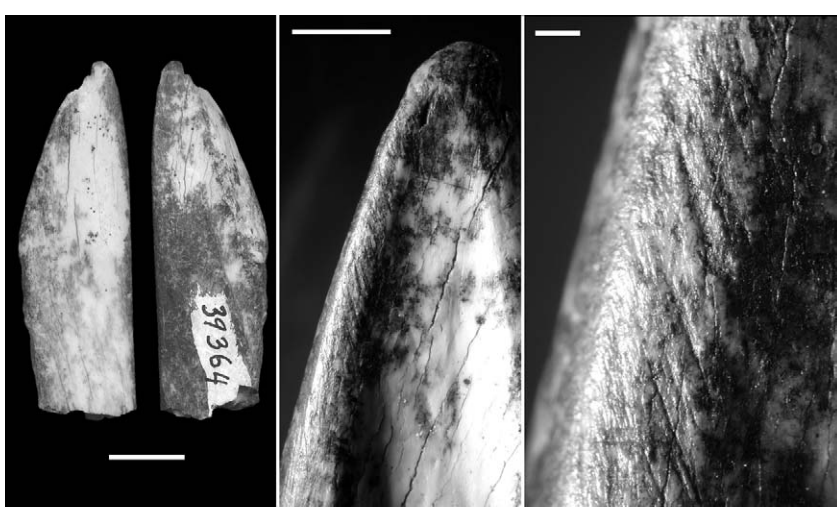

Fig. 4. Distal epiphysis of a medium-sized bovid right ulna showing possible traces of grinding. Left: scale = 1 cm; centre: scale = 5 mm; right: scale = 1 mm.

different degrees of abrasion. The most advanced stages produce a marked rounding of the exposed cortical and spongy bone (Fig. 9, bottom).

In none of the modern comparative and palaeontological collections studied have we found facets covered by parallel striations similar to those observed on the

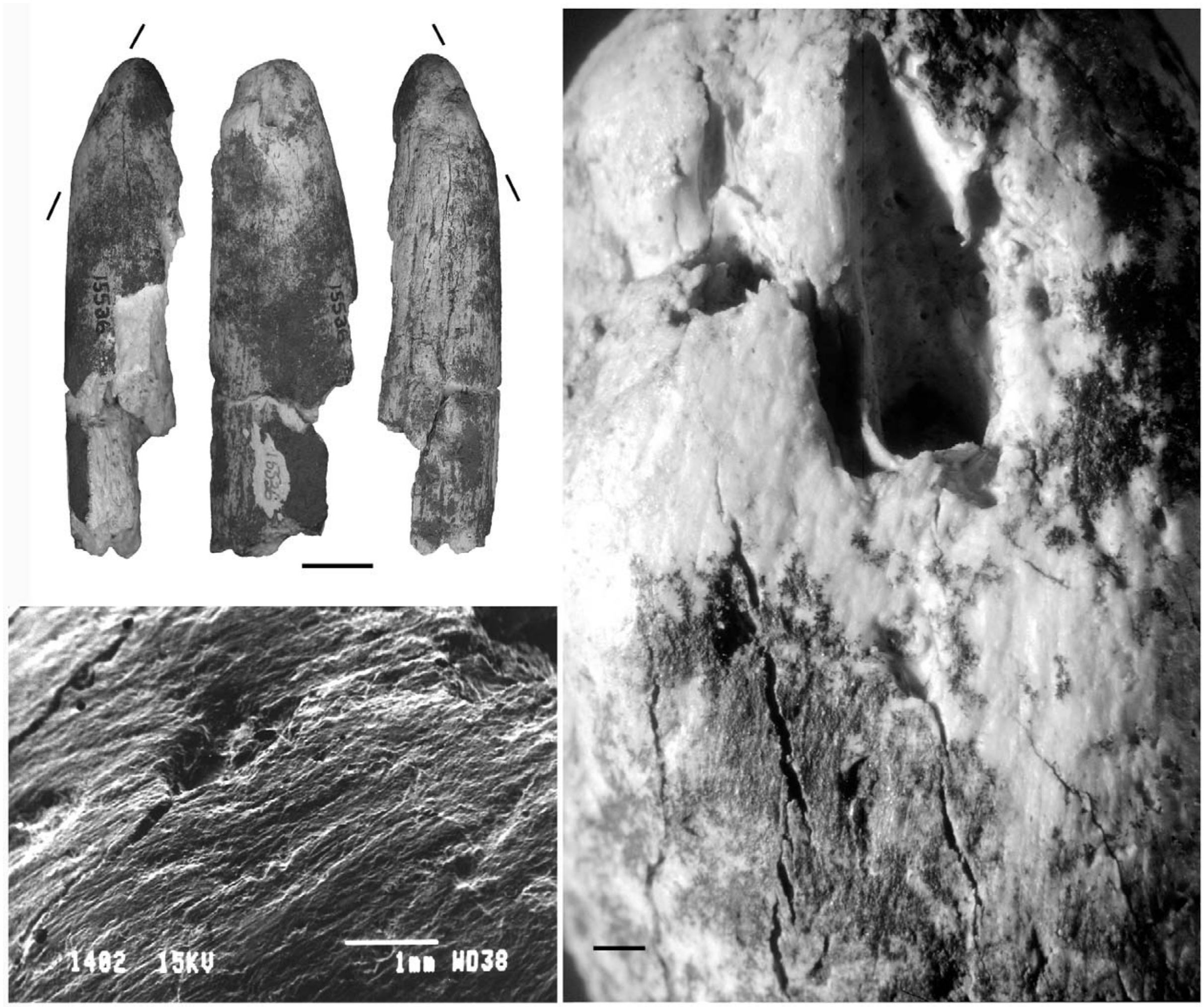

Fig. 5. Distal portion of horncore SKX 15536 bearing a facet covered by parallel striations. Upper left: scale=1 cm; right: scale=1 mm.

four Swartkrans horncore specimens. This pattern resembles that observed on archaeological, ethnographic and experimentally ground bone tools (Fig. 10). This bone shaping technique [41] produces characteristic fusiform, i.e. spindle-shaped striations whose breadth, depth and section depend on the hardness and cohesion of the grinding material, the pressure applied, and whether an additional abrading agent has been used during the grinding process. Most of the ethnographic and LSA bone tools shaped by grinding that we have examined were produced by pressing and vigorously moving the bone blank against coarse hard stone such as granite or quartzite, without adding any loose abrading material. The broad, deep, relatively short striations resulting from this process are similar to those recorded on the Swartkrans ulna (Figs. 4 and 10f). Those observed on the Swartkrans horncore facets are narrower, more superficial (Fig. 10e), and more closely match the pattern produced by us when experimentally grinding bone on sandstone or the outer crusts of termite mounds (Fig. 10d).

5. Discussion and conclusion

The four Swartkrans specimens with facets covered by parallel spindle-shaped striations represent idiosyncratic evidence. These features do not develop on horncore tips during the animal's life nor do they seem to have been caused by taphonomic agents or recent human intervention. Wear facets are naturally formed on living deer antlers [86] and elephant tusk tips, and the latter may be covered by oblique parallel striations [112]. This cannot be the case for the Swartkrans horncores as the facets were clearly produced after the death of the animal.

The occurrence of these traces on living animals indicates that extensive attrition from abrasion against rough surfaces and soil can create wear facets mimicking

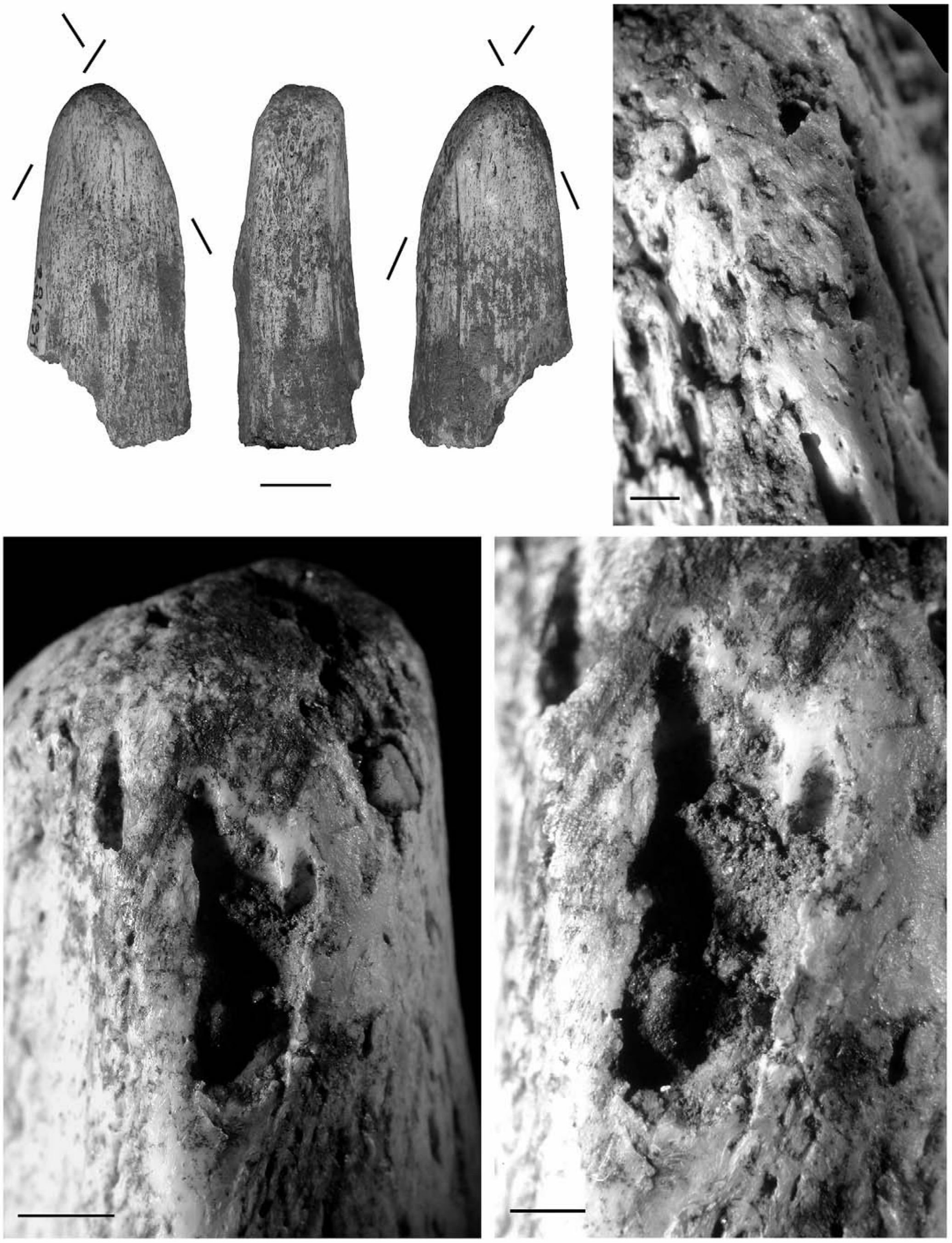

Fig. 6. Distal portion of horncore SKX 28437 with two facets covered by parallel striations. Upper left: scale = 1; bottom left: scale = 5 mm; top and bottom right: scale = 1 mm.

grinding. Thus one might argue that the facets on the Swartkrans specimens are anthropic but result from use rather than intentional shaping. However, facets recorded on Swartkrans horncores remove a large volume of the tool tip resulting in a clearly delimited ground area. This cannot be produced by a single misdirected motion in the course of the digging process. Experiments suggest that in order to achieve regular facets that drastically modify the tool shape you need repeated controlled motions.

The main difference between the traces recorded on the Swartkrans pieces presented here and those produced by trampling [3,12,13,48,87] is that the latter is characterised by groups of parallel randomly oriented striations of variable length and breadth, or superficial individual striations not observed on the former.

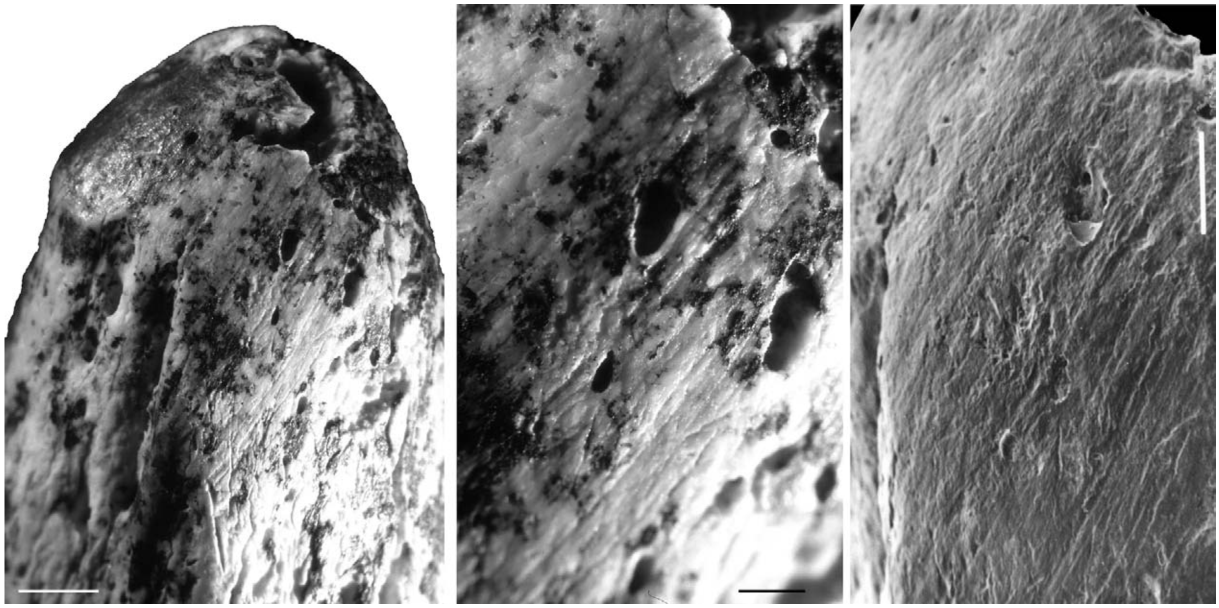

Fig. 7. Distal portion of horncore SKX 7068 showing a distinct facet (left) with clear parallel striations (centre and right). Left: scale = 2 mm; centre and right: scale = 1 mm.

Traces of grinding are also different from the wear pattern recorded on all the Swartkrans specimens interpreted as bone tools, and from that produced by the experimental use of the bone tools as digging implements. Digging activities—whatever the purpose and the environment in which they are conducted (termite mounds or tuber extraction)—never produce clear facets with parallel striations obliquely oriented to the main axis of the tool. The spindle-shaped surface features are similar to those observed on experimentally ground bone and on archaeological and ethnographic bone tools shaped by this technique. Does this constitute firm evidence that some of the Swartkrans bone tools were intentionally modified?

It is difficult to rule out the possibility that the localised grinding-like pattern seen on the ulna may have resulted from the sweeping of the bone tool against a rough surface during the digging activity since the ground facet on this specimen does not form an invasive facet on the tip. It is more difficult however, to propose this explanation for the facets on the horncores. If this was an occasional by-product of the digging process we would expect to find it on other bone tools from the collection as well as on experimentally used horn and bone tools, but this is not the case. Evidence of grinding systematically occurs on horncores, and is particularly developed on massive specimens, which, in addition, are the only pieces bearing opposing facets. These observations suggest that the facets are the result of deliberate modification of the horn tips. Considering the even plane of the facets and the dimensions of the striations, the horn tips were apparently abraded against an unconsolidated fine-grained matrix such as friable sandstone, solid ground or compacted sediment such as that constituting termite mounds.

What was the purpose of this modification and why was this technique only applied to horncores? The answer may be found in the study of the other bones used as tools.

Analysis of the breakage patterns and size of the Swartkrans bone tools, compared with the remainder of the faunal remains, indicate that the early hominid users selected heavily weathered, elongated and robust bone fragments [8,44]. Longitudinal fractures typical of weathered bone occur on 96% of the bone tools made on shaft fragments but on only 72% of the shaft fragments in the remainder of the assemblage. We know that the bone fragments were weathered prior to use and do not result from post-depositional breakage because 93% of the bone tools from shaft fragments with longitudinal weathered breaks show use-wear extending from the tip on these breaks [9]. Metric analysis shows that bone tools are a discrete population in that the few complete bone tools from the site are among the longest bone fragments found in the assemblage, and even the broken tools are generally longer. A similar result is obtained when the width of the tools and the thickness of the compact bone are compared with those of the unused fragments from the site.

Weathered long bone shaft fragments commonly available to hominids provided robust and relatively durable pointed blanks. Our digging experiments have shown that sturdy, weathered long bone fragments provide suitable digging implements, while fresh bone

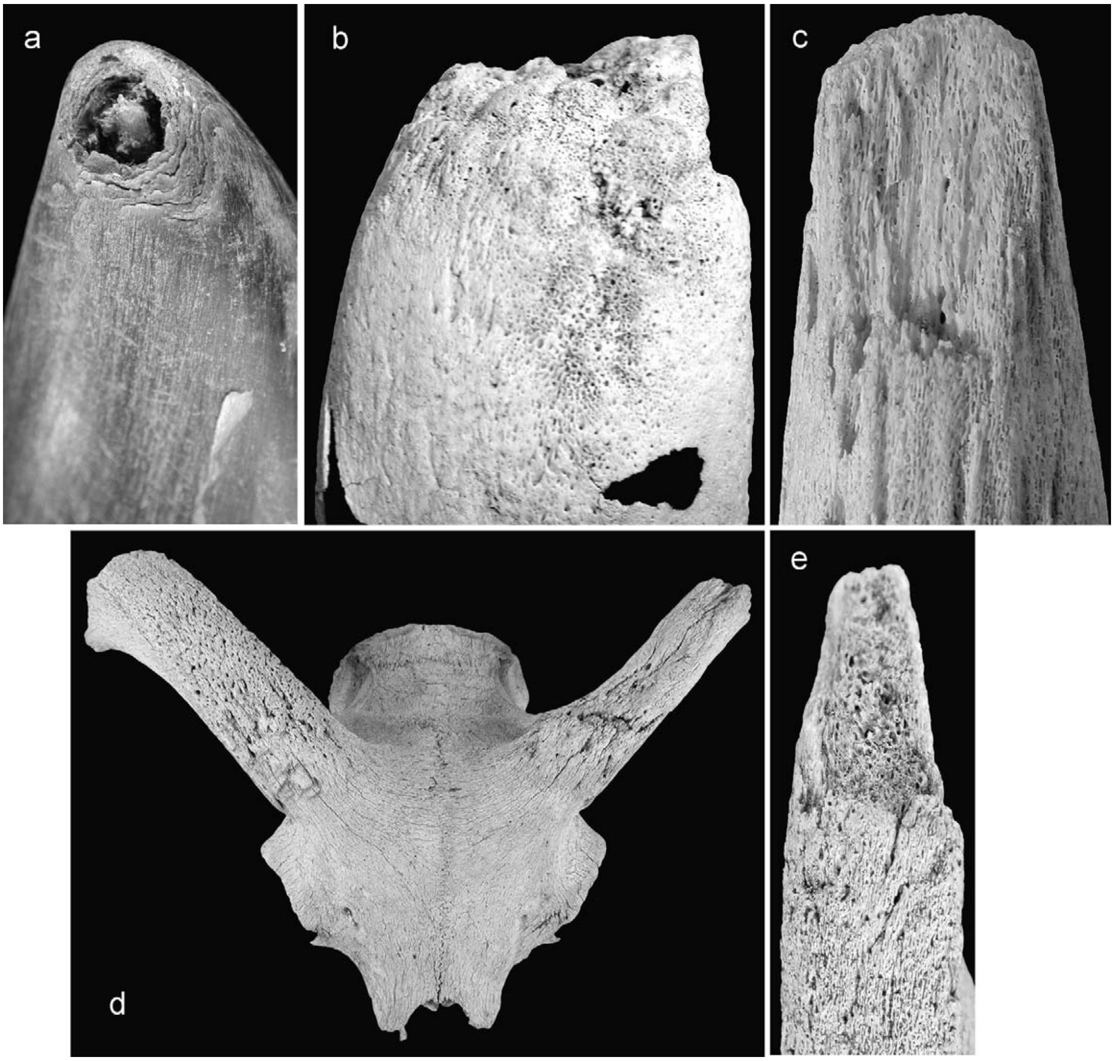

Fig. 8. (a) Cow horn showing intense wear of the sheath tip resulting in the exposure and marginal remodelling of the horncore apex; (b) cow horn affected by re-absorption of the bone tissue producing a shortening of the horncore and a bumpy appearance of the remodelled area; (c) flake damage on the tip of a cow horncore; (d) weathered skull of an ibex with broken and cracked horncores; (e) elongated break morphology on one of the horncores from the ibex skull.

Table 2
Modifications recorded on horncores from southern African Plio-Pleistocene sites

	Tip preservation			Degree of abrasion			Striations	Parallel striations	Facets	Total
	Complete	Clean break	Irregular break	Fresh	Slightly abraded	Heavily abraded				
Swartkrans Member 1	7	3	39	28	19	2		1	1	49
Swartkrans Member 2	4	6	63	33	28	12		2	2	73
Swartkrans Member 3	17	12	47	56	11	9	7	3	2	76
Makapansgat Member 3	3	10	20	17	3	13				33
Gondolin Main site		4	14	6	5	7				18
Sterkfontein Member 5		3	12	10	1	4				15
Total	27	38	195	150	67	47	7	6		264

fragments, which are stronger, have morphologies generally unsuitable for holding and digging purposes. Horncores offered large, easy to hold blanks. However, the loose structure of their bone tissue and the rounded tip morphology of horncores from a number of contemporary African taxa made them unsuitable for

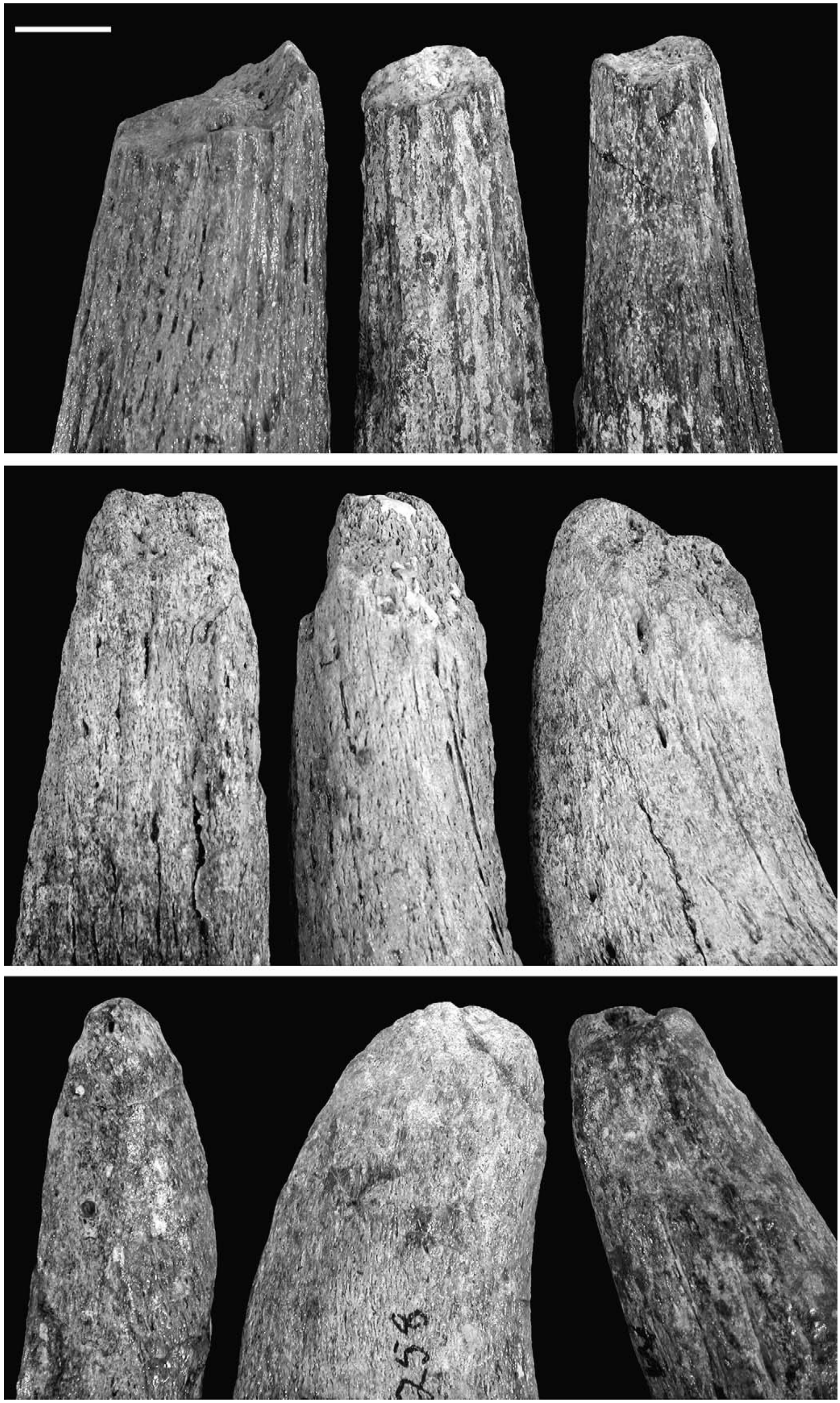

Fig. 9. Makapansgat horncores showing clean breakages due to fossil extraction (top), and varying degrees of erosion of the horn tip (centre, bottom). Scale=1 cm.

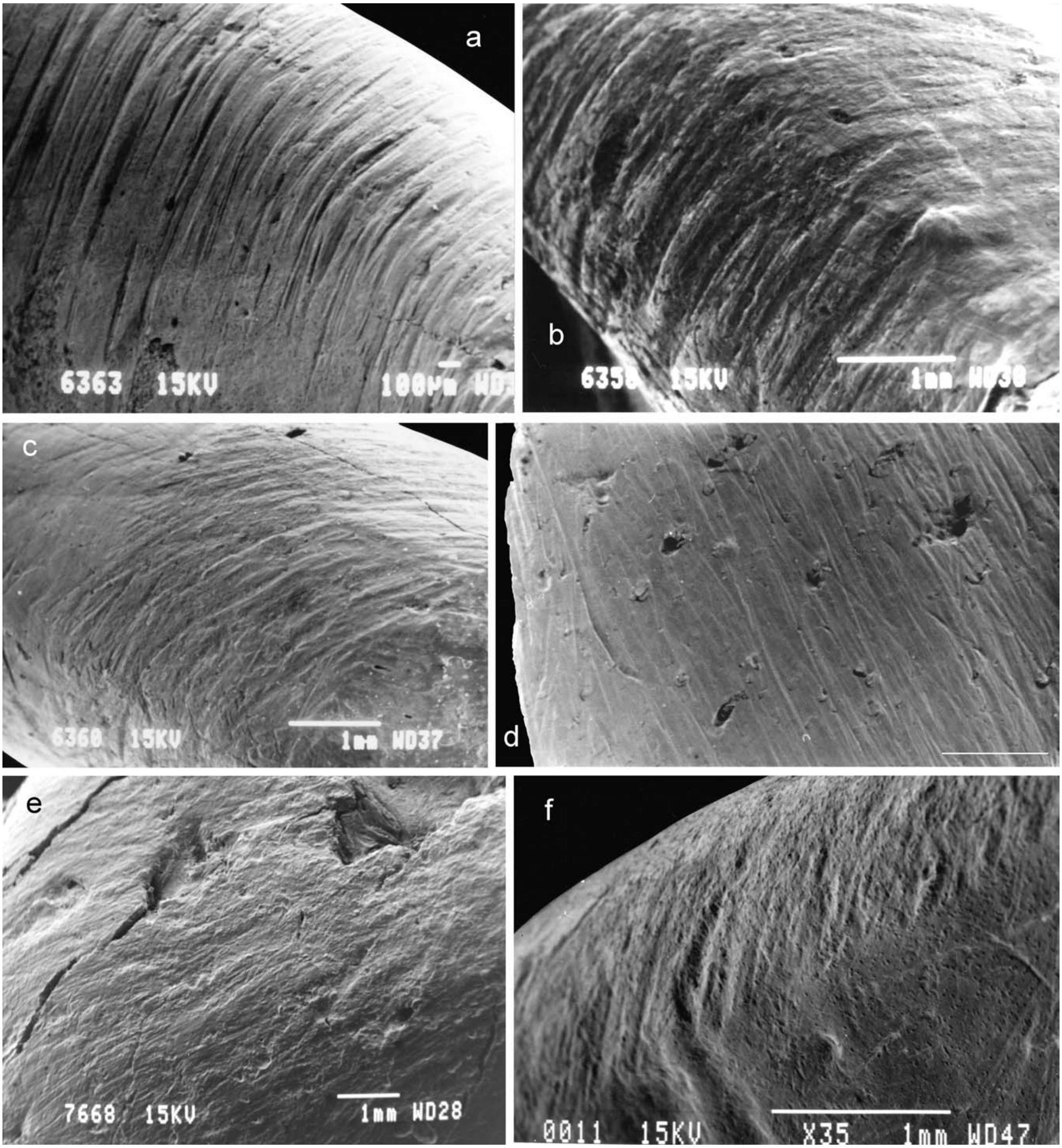

Fig. 10. SEM photos of traces of grinding on an aboriginal Australian bone point (a), Later Stone Age bone tools from Kasteelberg B (b) and the Hunterian Museum collection (c), a termite mound (d), and the Swartkrans horncore SKX 15536 (e) and ulna SKX 39364 (f). Scale in d = 1 mm.

prolonged use as implements for digging in compact sandy soils. This is demonstrated by our digging experiments which show that horncores become blunt and ineffective more quickly. The grinding of the horncore apex may represent a technical adaptation to overcome this problem. Grinding may have been used to shape horncore tips before using them in digging activities in order to improve their effectiveness, or to re-sharpen them when they became blunt and broad after a period of use. It is probable that both activities were performed. Our survey of patterns of horncore preservation suggests that most of the weathered horncores available to early hominids would have had tips eroded or fractured by taphonomic agents and that those with pointed breaks would have been used as they were. However, with use these would have rapidly become blunt and required

re-sharpening. On the other hand, our experimental digging shows that massive unbroken horncores, more resistant to taphonomic alteration, are ineffective for digging, and if selected by early hominids would have required modification prior to use.

How conscious was this technical behaviour, and was the final shape of the tool in some way predetermined? On none of the Swartkrans horncores is grinding used to produce formal tools, i.e. completely shaped artefacts such as those occasionally found at Middle Stone Age sites like Blombos [62], and with regularity in the LSA and the Upper Palaeolithic. However, the location and orientation of the facets on specimen SKX 28437 (Fig. 1g and Fig. 6) indicate that the tip morphology was foreseen. This horncore is elliptical in section with the two facets located on the narrower aspects, thereby creating a sturdy point at the tip. Had the wider sides been reduced, the tip would have become a fragile ridge, inefficient for digging purposes. This suggests that the makers had a clear understanding of the relationship between the orientation of the tool during grinding, the location of the resulting facets, the final shape of the tip and its efficiency and longevity as a digging implement. In other words, though bone tool shaping at Swartkrans was not conducted to manufacture formal artefacts, it none the less suggests that the makers had the cognitive ability to understand the properties of bone and conceive a shaping technique specific to this raw material. The invention of techniques specific to bone, antler, ivory and horn, and the production of tools in these materials have often been considered as an archaeological signature of modern human behaviour, intimately associated with the emergence of anatomically modern humans [2,62,71,74,79–82,102]. It has been shown however, that shaped formal bone tools were produced by late Neandertals at several French sites [43] indicating that this behaviour is not specific to our species. The evidence from Swartkrans suggests that the deliberate modification of bone by means of a technique specific to this material may considerably predate the first *Homo sapiens* populations. This indicates that the mere application of grinding to bone cannot in itself be considered as a hallmark of behavioural modernity. It is rather the application of this and other bone shaping techniques to produce standardised bone artefact categories showing regional and chronological variation that should be considered, if any, as a viable signature of a complex cultural system. The search for patterns of variation between the bone tools from Swartkrans Members 1–3 (ca. 1.8–1.0 Mya) reveals that no significant differences exist in the type and size of the blanks used, as well as in the wear pattern recorded on the tools, suggesting that these artefacts reflect a subsistence activity that remained unchanged for nearly a million years. Notably, evidence of grinding also spans Members 1 to 3 indicating that this technique does not appear as an innovation within an existing cultural tradition, but rather represents an integral component of a long standing subsistence strategy.

This strategy certainly would have included the use of horns covered by sheaths. The keratin covering remains firmly attached to the horncore long after the death of bovids and provides an ideal, durable digging tool. It may well be that the recorded systematic use of horncores at Swartkrans and Drimolen ([67]; Kuman, pers. com.) represents only a fraction of a larger organic tool kit used by early hominids.

Who used these tools? Cranial capacity and architecture have historically been the accepted measure of cognitive ability, and as such have been pivotal in the separation of taxa, with culture traditionally assigned to *Homo*. This assumption no longer seems tenable in light of the fact that stone tools predating the emergence of *Homo*, and contemporaneous with the robust australopithecines were already in existence in sites in Ethiopia at around 2.5 Mya [57,64,94]. Since both *Paranthropus* and early *Homo* are associated with bone tools, the question remains as to who made them. Members 1–3 at Swartkrans contain the remains of the robust australopithecine, *Paranthropus (Australopithecus) robustus*. Members 1 and 2 have yielded the remains of a second hominid designated *Homo erectus*[23,34]. While the absence of *Homo* remains in Member 3—where the largest collection of bone tools was found—may suggest these artefacts were utilised by *Paranthropus robustus*, this does not constitute firm proof. Both hominid types are attested at Drimolen [68], the other southern African site to have yielded a consistent collection of bone tools. Here there is a virtual absence of stone tools, which considering the low number of lithics found in Swartkrans Member 3, may indicate that the bone tools were used by *Paranthropus robustus*. Another reason to favour this hypothesis is that while stone tool technology persists well after 1 Mya, no bone tools similar to those from Swartkrans have to date been found in layers post-dating 1 Mya, the time of the robust australopithecine extinction in southern Africa [22].

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